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A DEVICE FOR THE INDIRECT RECORDING OF BLOOD PRESSURE

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NOTICES

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WRIGHT AIR DEVELOPMENT CENTER
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UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

This report was prepared in the Acceleration Section, Biophysics Branch, Aero Medical Laboratory, under the authority of Project No. 7216 "Physiology of Acceleration". Lt. G. D. Zuidema, USAF(MC), Dr. Robert Edelberg and Lt. Edwin W. Salzman, USAF (MC) served as the principal investigators.

The authors wish to acknowledge the help of Mr. W. J. White and Mr. James E. Smithson, Psychology Branch, for their statistical treatment of the raw data.

ABSTRACT

A device for the repeated recording of blood pressure without arterial puncture has been developed for use in the experimental work on the heart and circulation. Pulse waves from the brachial artery are picked up by a plastic balloon underlying the conventional blood pressure cuff and recorded by means of a Statham pressure transducer and an oscillograph. The cuff is automatically inflated every 30 seconds and a tracing of the pressure fall recorded on the same paper. Since the systolic and diastolic pulse waves are easily recognized, their respective pressures are found by reference to the record of the pressure fall recorded simultaneously.

This method, successfully employed in 90 determinations on 10 subjects, gave good results; the values agreeing accurately and consistently with those obtained by conventional means. Such a system should prove useful in wide areas of experimental work, including studies of the response of the body to stress. Its use in the high altitude low pressure chambers is described.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF(MC)
Chief, Aero Medical Laboratory
Directorate of Research

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SECTION I

INTRODUCTION

In many fields of investigation it is important to follow the cardiovascular status of the subject by means of his blood pressure and pulse changes. This is especially true in the study of acceleration and high altitude flight where cardiovascular responses become all-important. It is also convenient to have a graphic record of these parameters for purposes of study and illustration. A device for the automatic recording of the blood pressure and pulse is desirable because it performs these function and has the additional value of freeing one member of the research team from the task of recording pulse rate and blood pressure at frequent intervals throughout the experiment.

The direct method for recording blood pressure is by means of an intra-arterial needle connected to a manometer and recording system. A technique requiring arterial puncture is, for obvious reasons, less acceptable to the subject than an indirect bloodless method.

SECTION II

REVIEW OF THE LITERATURE

A number of investigators have been interested in the development of a device for the automatic recording of blood pressure. In 1901, Von Recklinghause (1) employed an arm and a manual pump. The cuff was inflated to a pressure sufficient to occlude the brachial artery and allowed to deflate slowly. Systolic pressure was considered that point at which the systemic arterial pressure was just sufficient to overcome the pressure within the cuff. The pulse waves, as transmitted to the cuff, were recorded on a smoked drum. Under this system, the first abrupt increase in amplitude of the pulse waves was considered systolic pressure; diastolic pressure was recognized by a decrease in the amplitude. In 1908, Erlanger (2) developed an instrument based on this same principle and also noted that not only did the amplitude increase as systolic pressure was reached, but that the pulse wave was changed in form at this point, manifested by a wider separation of the ascending and descending strokes. Von Recklinghause (1), Erlanger (2) (3), MacWilliams and Melvin (4) carried out extensive studies on the distensibility of arteries and the configuration of the pulse wave. Von Bonsdorff (5) utilized a Broemser glass plate optical manometer to take and record blood pressure while Gilson (6) and Weiss (7) employed a type of microphone overlying the brachial artery to record the sounds as they appeared and disappeared with pressure alterations within the cuff.

SECTION III

EQUIPMENT AND PROCEDURE

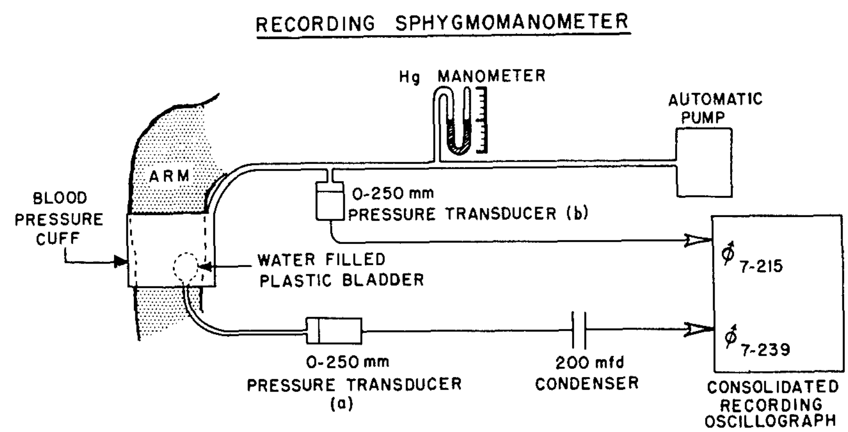

Figure 1. Diagramatic presentation of the components of the recording sphygmomanometer.

Two of the basic components of the present system (Figure 1) are similar to those employed in previous devices for the automatic recording of blood pressure. These consist of a conventional blood pressure arm cuff and an electric pump which is used to inflate the cuff. This pump has been modified so as to automatically perform the inflation in one or two seconds and then shut off upon reaching the desired pressure of 240 mm Hg. The pressure is then allowed to subside to ambient over the next 22 to 24 seconds. The entire cycle, approximately 25 seconds long, is then repeated continuously until terminated by the operator. A mercury manometer in the circuit allows reading of the pressure in the cuff at any given time, and is also used for calibrating the system. The pressure fall within the cuff is followed by means of a Statham pressure transducer (b) recording on a Consolidated oscillograph with a 7-215 galvanometer with a sensitivity of 13 micro amps. per inch.

The pulse waves are picked up by a fluid-filled plastic balloon which fits beneath the cuff and overlies the brachial artery (Figure 1). The waves are transmitted through a fluid filled polyethylene catheter to a Statham transducer (a) for recording on the oscillograph with a 7-239 galvanometer with a sensitivity of 4 micro amps. per inch. A conventional type of blood pressure cuff has been modified to include such a plastic balloon and its associated transducer (a) as a single unit, thus greatly simplifying the attachment of the components to the individual subjects. The recording of the transducer (b) showing the fall of pressure within the cuff appears simultaneuosly with the recording of the individual pulse

waves from the balloon. The use of a 200 to 1000 mfd condenser in series with the output of the transducer (a) serves to flatten out the baseline by eliminating the large, slow drop in pressure within the cuff, while preserving the smaller pulse waves from within the balloon (Figure 2).

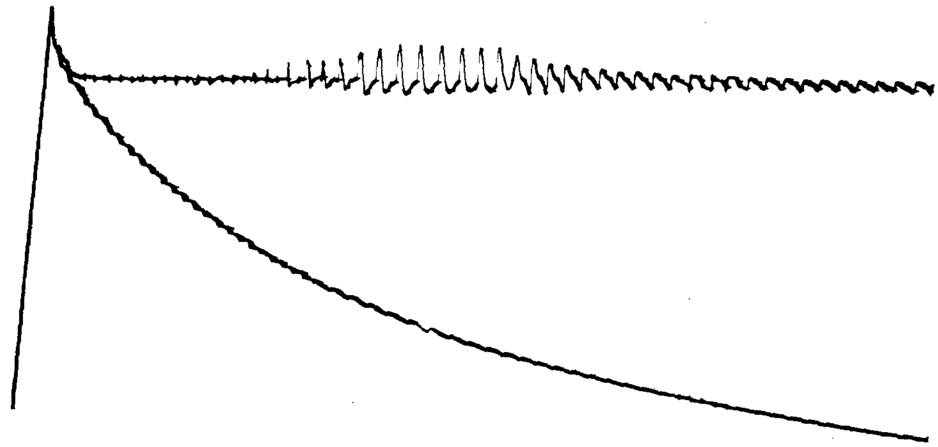

Figure 2. Oscillograph record showing pulse (upper, horizontal line) and record of pressure within the cuff(falling line).

Since the systolic and diastolic configurations are easily recognized (1) (2) (4) (Figure 3), their respective pressures are determined by reference to the point on the calibrated pressure curve at which they appear.

With modifications, this system was used within the low pressure-high altitude chambers in excess of 60,000 feet. Under these circumstances, both pressure transducers were placed within the chamber. Boiled water was used in the balloon-transducer system to avoid bubble formation at altitude. The air-containing cuff-transducer system was opened to the chamber atmosphere during ascent to assure a constant pressure differential across the transducer membrane. The blood pressure cuff was inflated at altitude by opening the system to outside atmospheric pressure, and was deflated by bleeding it into the chamber.

SECTION IV

RESULTS AND DISCUSSIONS

Ninety determination were carried out on 10 subjects to compare the blood pressure as taken by the automatic recording method with that taken by auscultation. The readings were performed in a random order by three physicians, each of whom kept his results independently. In every case, the diastolic pressure was noted both when muffling of the sounds occurred and upon their disappearance. At the conclusion of the experiment the results

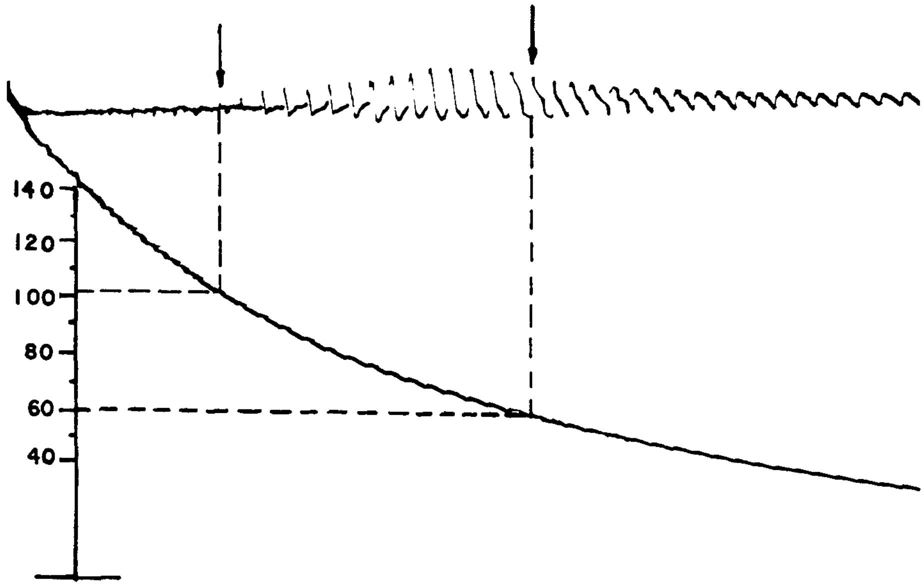

Figure 3. Oscillograph record with the systolic and diastolic pressures marked (arrows), and calibration of cuff pressure added at the left. Dotted lines show how systolic and diastolic pressures are determined by referencing the cuff pressure.

of the recorded and auscultatory blood pressures, which had been taken simultaneously, were paired for purposes of comparison and statistical treatment.

Statistical analysis revealed a correlation coefficient of 0.97 between the auscultatory and automatic recording methods. The automatic measurements also demonstrated a greater degree of constancy from one determination to the next than was seen in those determined by auscultation.

From this analysis we may conclude that the automatic method agrees well in accuracy with auscultatory methods in the hands of a physician. The recorder is also subject to the same limitations as auscultation. That is, both are indirect measures and depend upon the use of an occlusive cuff. The accurate use of either method demands at least 20 seconds to allow for enough pulse beats to come through for clear detection of systolic and diastolic pressures. This precludes the use of the automatic method for determination of pulse pressure at a given instant in time. However, few situations demand such speed, and therefore the recorder fills a wide range of usefulness. An automatic recorder has the additional advantage of removing the possibility of subjective error in the process of listening for beats. It also removes whatever psychological effect there might be related to the presence of a physician.

A number of authors have studied the relationship of various indirect methods for the measurement of blood pressure with actual intra-arterial determinations. Hamilton, et al (8) found that in a series of 30 comparisons, the indirect cuff method gave readings averaging three to four millimeters of mercury lower for systolic and nine millimeters of mercury higher for diastolic than the direct reading. Steele (9) also compared auscultatory with intra-arterial determinations. He showed that systolic pressure was underestimated in auscultation by about 10 mm Hg, and felt, as did Bordley, et al (10), that disappearance of the sounds was a more accurate measure of diastolic pressure than muffling, or the 4th phase of Korotkow. On the other hand, Roberts, et al (11), felt that muffling was more reliable in denoting diastolic pressure. It was our experience that diastolic pressure, as determined by the disappearance of sounds, agreed more closely with diastolic pressure measured automatically.

Van Bergen, et al (12), compared three indirect methods with direct determinations. In their study, oscillometric recording, auscultatory and palpatory methods were found to agree in that order of descending accuracy. Their most accurate method, i.e., oscillometric, described systolic pressure as the point at which the meniscus of the pulsating mercury column of the manometer became convex. Diastolic pressure by this method would be of questionable accuracy. In their case, all indirect readings fell slightly below direct measurements and, as pressure rose, the indirect readings fell farther below direct.

SECTION V

STATISTICAL ANALYSIS

The mean difference in systolic pressures, as measured by auscultation and recorder, was 1.1 mm Hg, with a standard deviation of 5.05 mm Hg. The mean difference does not appear to be significantly different from a postulated zero difference, when compared by a t-test. It seems safe to conclude that over the combination of physicians, times and subjects employed in the experiment, no difference is expected to occur between the measurements taken by the two methods. However, the expected limits of chance variation are, in 95 % of the cases, ± 2.59 (5.05) or ± 13.08 mm Hg, and in 90 % of the cases, ± 6.6 mm Hg. The coefficient of correlation of systolic measurements by the two methods is 0.95.

The mean difference is diastolic pressures was 2.38 mm Hg, with a standard deviation of 5.48 mm Hg. This mean difference is significantly different from a postulated zero difference by t-test. Thus, auscultatory measurements by disappearance of the sound are, under these conditions, slightly higher than recorder measurements, on the average. This difference is subject to chance variations of about the same magnitude as those obtained in systolic measurements. The coefficient of correlation of diastolic measurements was 0.95.

Auscultatory measurements by three physicians were treated by analysis of variance. In the course of 30 determinations by each physician, systolic pressures were found to vary on an average of 3.0 mm Hg. From this it can be seen that the mean difference between determinations by the automatic method is less in both cases than the expected difference between any two physicians.

SECTION VI

SUMMARY

1. An indirect method for the repeated recording of blood pressure in man is described.

2. Statistical validation of the method is submitted.

3. Successful use of this system in the high altitude chamber is reported.

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